AD-A037 144   ARMY COMBINED ARMS COMBAT DEVELOPMENTS ACTIVITY FORT--ETC F/G 19/3
              EFFECTIVENESS OF THE CAMOUFLAGED M60A1 TANK.(U)
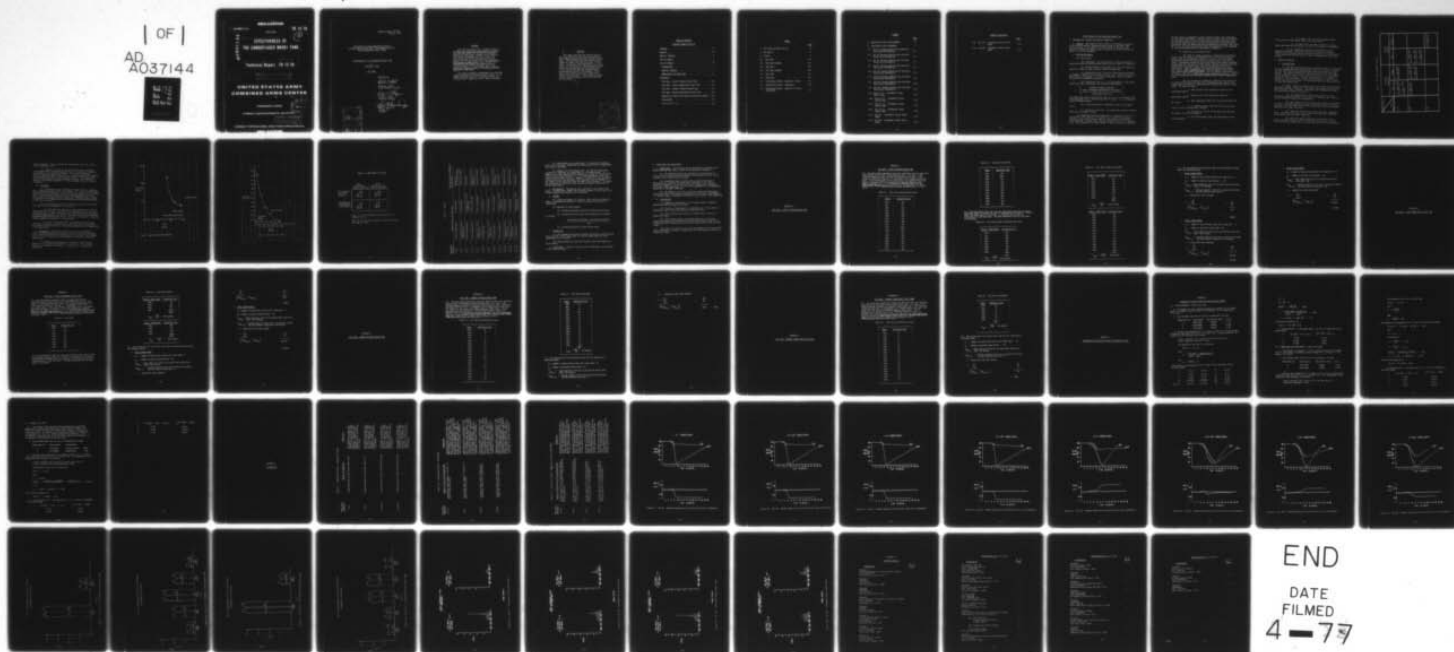   NOV 76   J L RIGGS
UNCLASSIFIED   CACDA-TR-12-76   NL

| OF |
AD
A037144

END
DATE
FILMED
4-77

NOVEMBER 1976

TR 12-76

ACN 23874

ADA037144

EFFECTIVENESS OF THE CAMOUFLAGED M60A1 TANK.

CACDA-

Technical Report TR-12-76

Jeffrey L. Riggs

UNITED STATES ARMY COMBINED ARMS CENTER

COMBINED ARMS

DDC

MAR 21 1977

COMBAT DEVELOPMENTS ACTIVITY A

COMBAT OPERATIONS ANALYSIS DIRECTORATE

Directorate of Combat Operations Analysis
US Army Combined Arms Combat Developments Activity
Fort Leavenworth, Kansas 66027

EFFECTIVENESS OF THE CAMOUFLAGED M60A1 TANK

by
Jeffrey L. Riggs

ACN 23874

Approved by:

Richard C. Rinkel
Chief, Analysis Division

Leland C. Pleger
Technical Director

Reed E. Davis, Jr.
Colonel, IN
Director

ABSTRACT

This paper describes the results and con-
straining factors of a military worth analysis
that compared camouflaged versus pattern-painted
tanks. The Battalion Level Differential Model
(BLDM) was used as the analytical tool for this
study. The analysis described herein is a com-
parison of the results of simulated battles; some
battles with camouflaged pattern-painted tanks
in the defense and some with noncamouflaged
pattern-painted tanks in the defense. In all
cases, the offensive force was a numerically
superior Red tank force. The analysis is based
on test data collected at the US Army Aberdeen
Proving Ground.

iii

TABLE OF CONTENTS

Technical Report TR 12-76

TABLES

FIGURES

FIGURES (concluded)

vii

EFFECTIVENESS OF THE CAMOUFLAGED M60A1 TANK

1. INTRODUCTION: PURPOSE AND WORKING PARAMETERS.

   a. Purpose. The purpose of this report is to document an analysis of the military worth of camouflage applications to the M60A1 tank. For the purpose of this analysis, military worth is defined as the effect of a particular factor (such as acquisition) on the expected outcome of a military engagement.

   b. Working Parameters.

      (1) Definitions.

         (a) Camouflage: For this analysis, various applications of camouflage placed on pattern-painted tanks with the intent of disguising.

         (b) Pattern-painted: The application of various colors and patterns of paint to tanks with the intent of disguising.

         (c) Acquisition time: The sum of times required to detect a silhouette, identify the silhouette by type (i.e., tank) and force (i.e., Red or Blue), and acquire (i.e., bring the observer's weapon to bear on the previously undetected silhouette).

         (d) Acquisition rate (λ): For the purposes of this paper, acquisition rate is defined as the following relationship;

$$\lambda = \left\{ \frac{\dfrac{\text{number of targets acquired}}{\text{number of targets available for acquisition}}}{(\text{time spent acquiring})} \right\}$$

This method was used to transform the test data into a form usable by the simulation model used in the military worth analysis; i.e., the Battalion Level Differential Model.

         (e) Firing acquisition: Acquisition cued by the target firing.

         (f) Nonfiring acquisition: An acquisition caused by factors other than the target firing.

      (2) Camouflage related to acquisition. Acquisition rate (λ) is the basis for this analysis. The definition of acquisition time as a function of the time to detect, identify, and acquire is relatively straightforward. However, there are many factors implicit in an acquisition. They include, but are not limited to, range, visibility, observer's

ability, terrain, vegetation, static or dynamic state, paint techniques, and camouflage application. The test that is the basis for this analysis was designed to hold all these factors constant except camouflage, which was the controlled variable. By carefully observing and collecting the acquisition times for camouflaged and noncamouflaged situations, the stage was set for calculating acquisition rates and transferring this knowledge of a nonfiring acquisition to a battlefield simulation.

  (3) Acquisition on the battlefield.

   (a) There is another dimension to battlefield acquisition, which is not discussed in the paragraph above. Acquisition cued by a target firing is an undeniable aspect of a battle. The "real world" relationship between firing and nonfiring acquisitions is not well defined. Information gathered by the US Army Combat Developments Experimentation Center for the Tactical Effectiveness Testing of Antitank Missiles (TETAM) Evaluation comes closer than any reviewed to defining this relationship. Specific documents reviewed were BDM Services Company Final Report, TETAM Extended Analysis dated 24 December 1974, and US Army Combined Arms Combat Developments Activity Technical Memorandum 1-74 of 26 April 1974 titled TETAM Effectiveness Evaluation, Phase II. However, the TETAM evaluation did not explore acquisition of firing, camouflaged tanks.

   (b) As the analysis progressed, questions arose pertaining to firing acquisitions that could not be answered without making large assumptions, which might in themselves have dictated the results of this study. The questions were:

   <u>1.</u> What are the firing acquisition rates for non-camouflaged tanks?

   <u>2.</u> What are the firing acquisition rates for camouflaged tanks?

   <u>3.</u> Does camouflage affect the firing acquisition rate of a tank?

   <u>4.</u> If camouflage does affect the firing acquisition rate of a tank, is range also a factor?

   <u>5.</u> If range is a factor in the above case, what are the details of this relationship?

   <u>6.</u> Do firing targets affect the acquisition of non-firing targets?

7. If 6. above is yes, how does distance between firing and nonfiring targets affect this relationship?

8. Can acquisition rate data collected in a test, where camouflage was not applied, be used in an analysis of camouflage?

(c) No assumptions concerning the answers to these questions were made. The choice was made to bracket all possible effects of firing acquisition by having one series of runs emphasizing firing acquisition and one series of runs not emphasizing firing acquisition.

2. ANALYSIS OVERVIEW.

a. Available Data.

(1) The data provided consisted of cumulative times of acquisition for test (camouflaged) and pattern-painted tanks as a function of range. The test tanks were pattern-painted tanks with and without camouflage applied. The ranges correspond to measured markers on the test course, and the cumulative times represent the total time spent by the observer trying to acquire a target. The data are presented in appendixes A through D. The calculations involved in determining the specific acquisition rates are also included. It should be noted that these rates are all nonfiring acquisitions.

(2) Table 1 shows the characteristics of the test runs for which data were provided. The range is the approximate maximum range at which acquisition was first attempted. Test runs 1 and 5 represent the basis for this analysis because (see table 1):

(a) The complexities of night battle simulations were considered beyond the bounds of this analysis; therefore, test runs 4, 8, 6, and 7 were eliminated from consideration.

(b) Both dynamic and static acquisition rates were required in order to calculate both Red and Blue acquisition rates from the same data base. Two test runs, one moving and one dynamic, that had the same characteristics, had to be used.

(c) Data were required from tests with common vegetation cover. Therefore, test runs 2 and 11 were eliminated since there were no stationary runs with heavy vegetation.

(d) Data were required from tests with common terrain features (either rolling or flat); therefore, test runs 3 and 10 were eliminated because there were no "moving" runs with rolling terrain and

3

Table 1. Test data available for use

Conditions / Max Range of Test	(Target) Stationary		(Target) Moving	
	Day	Night	Day	Night
3 Km	#10 Light Vegetation/Rolling #1 Light Vegetation/Flat	#4 Light Vegetation/Rolling		
2 Km	#3 Light Vegetation/Rolling	#8 Light Vegetation/Flat #6 Heavy Vegetation/Rolling	#5 Light Vegetation/Flat #2 Heavy Vegetation/Rolling #11 Heavy Vegetation/Rolling	
1 Km				#7 Heavy Vegetation/Rolling

4

light vegetation. Thus, by process of elimination, test runs 1 and 5 were the candidate runs.

(3) Figure 1 is a plot of the acquisition rates calculated in accordance with the methodology described in appendixes A through D. An expansion of the data was performed. Based on the assumption that the calculated acquisition rates fit a negative exponential equation and the acquisition rates at other ranges would fit these same curves, the data were expanded into two exponential curves. This expansion process is described in appendix E. These expanded curves are plotted on figure 2.

b. The Model.

(1) The Battalion Level Differential Model (BLDM) is a force-on-force differential model of small unit combat. It included movement and direct fire for this analysis. The model executes rapidly and is a useful tool for the parametric investigation of weapon parameters and mixes. (For a more detailed description of BLDM, see CACDA/COA Technical Paper of June 1976 titled Analysis of Antiarmor System Effectiveness with BLDM by MAJ Larry M. Pigue.)

(2) The variables used for this analysis were nonfiring acquisition rate and firing probability of acquisition.

(a) For nonfiring acquisition (the target had not fired in the preceding 10 seconds), if line of sight existed, the model took the acquisition rate λ from a table based on target mode (static or dynamic) and range between observer and target. The test data for camouflaged and noncamouflaged tests were used to fill this table. The value λ was then used to compute the probability of acquisition.

(b) For firing acquisition (the target had fired in the preceding 10 seconds), the model was run using two constant values for the probability of acquisition. These values emphasized and de-emphasized firing acquisition.

c. Run Design. The approach shown in table 2 was designed to provide relative comparisons of the three factors that affect the model. Table 3 shows the relationship between runs to be compared, their common factors, and the constraining factor between the two runs. The three factors were:

(1) Expanded or nonexpanded (see paragraphs 1a(4) above or appendix E for a detailed description of expansion): The negative exponential assumption was treated as a factor, but it proved to be unimportant.

5
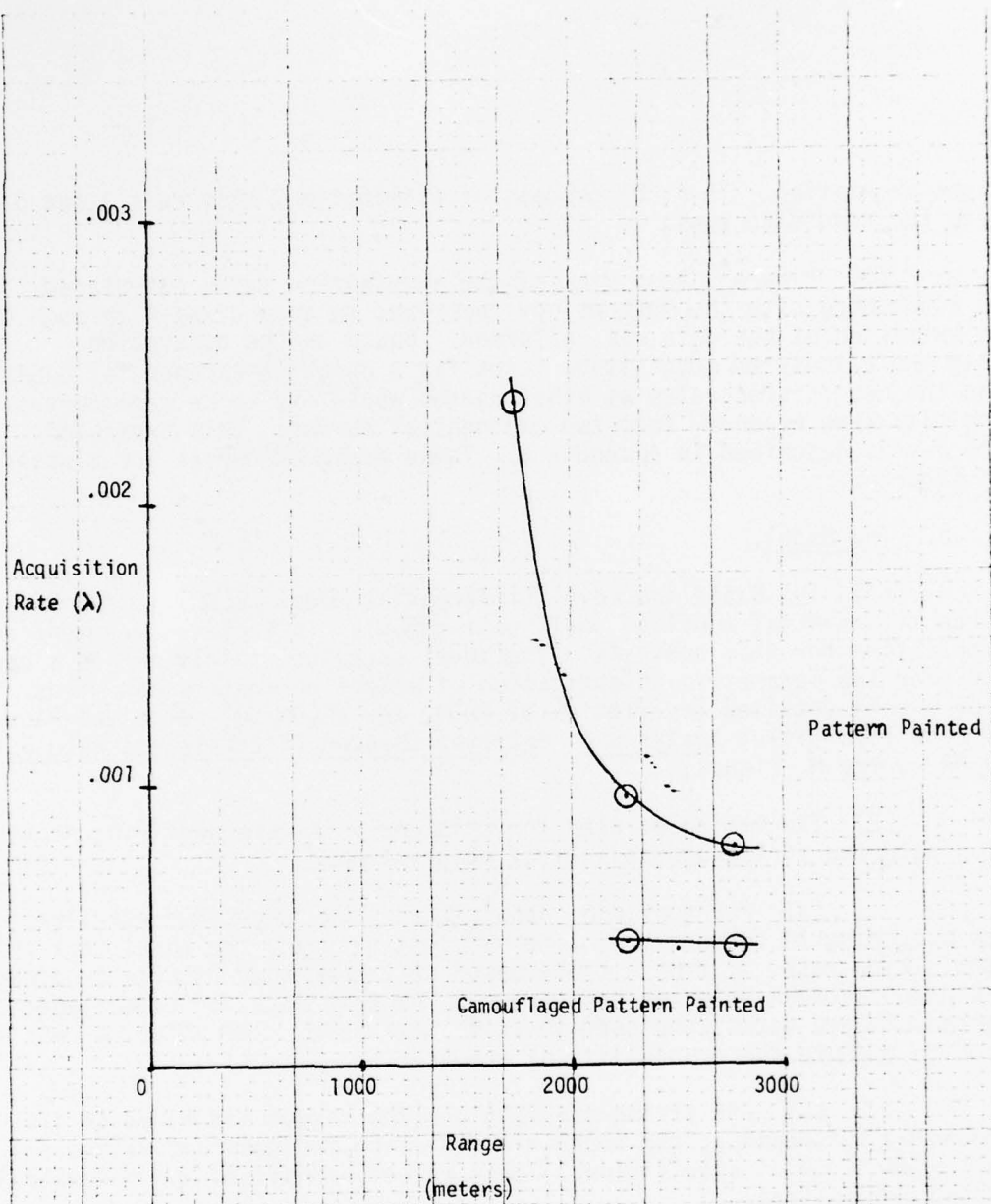
Figure 1. Acquisition Rates (Non-expanded)

6

Figure 2. Acquisition rates (expanded)

7
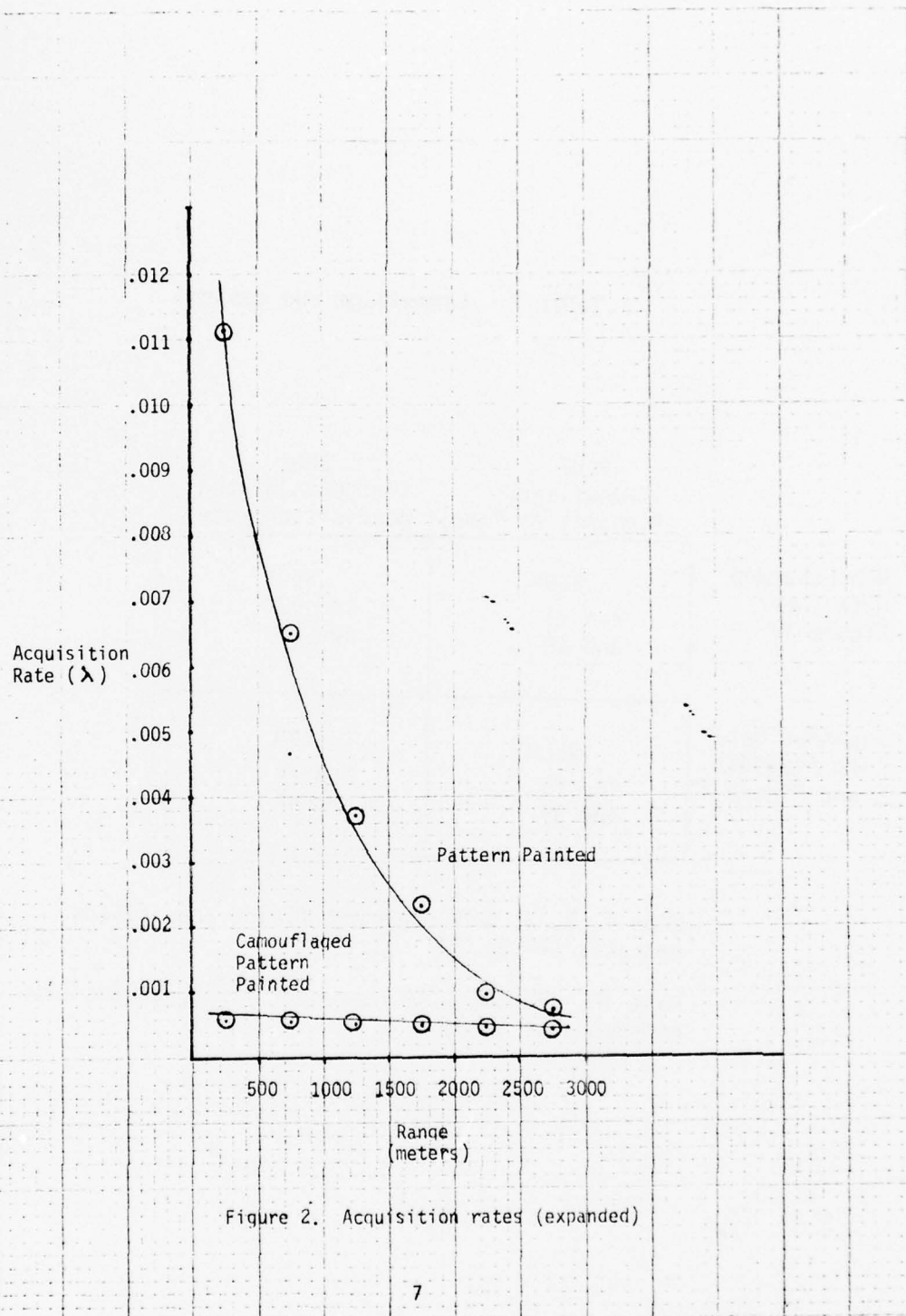
Table 2. Camouflage run design

	BLUE (Camouflaged Acquisition Rate)	BLUE (Pattern Painted Acquisition Rate)
Non-Expanded Data (See Figure 1)	BLDM Run #1 and 1P	BLDM Run #2 and 2P
Expanded Data (See Appendix E and Figure 2)	BLDM Run #3 and 3P	BLDM Run #4 and 4P

Runs 1, 2, 3, & 4 represent firing acquisition emphasis (P=.3).

Runs 1P, 2P, 3P, & 4P represent firing acquisition non-emphasis (P=0).

8

Table 3. Factors

Runs Being Compared	Common Factors for Both Runs		Contrasting Factors Between The Two Runs
1 & 1P	1) Non-expanded data	2) Camouflaged	Emphasis of firing acquisition
1 & 3	1) Emphasis of firing acquisitions	2) Camouflaged	Expansion of data
1 & 2	1) Non-expanded data	2) Emphasis of firing acquisition	Camouflage
2 & 2P	1) Non-expanded data	2) Not camouflaged	Emphasis of firing acquisition
2 & 4	1) Emphasis of firing acquisition	2) Not camouflaged	Expansion of data
3 & 3P	1) Expanded data	2) Camouflaged	Emphasis of firing acquisition
3 & 4	1) Emphasis of firing acquisition	2) Expanded data	Camouflage
4 & 4P	1) Non-expanded data	2) Not camouflaged	Emphasis of firing acquisition
1P & 2P	1) Emphasis of firing acquisition	2) Camouflaged	Camouflaged
1P & 3P	1) Emphasis of firing acquisition	2) Camouflaged	Expansion of data
2P & 4P	1) Emphasis of firing acquisition	2) Camouflaged	Expansion of data
3P & 4P	1) Expanded data	2) Emphasis of firing acquisition	Camouflaged

9

(2) Camouflaged or not camouflaged: The explicitly important factor in this analysis represented by changing the nonfiring acquisition rate table in the model.

(3) Emphasis on firing acquisition: An implicit factor that is equally as important as "camouflaged" or "not camouflaged." An emphasis on firing acquisition was obtained by setting the firing probability of acquisition constant at .3. For the non-emphasis cases, the constant was put equal to zero. "Emphasis" is meant to imply the highest firing acquisition rate the model could represent, and non-emphasis is the lowest firing acquisition rate the model could represent. The intent was to bracket all possible firing acquisition rates by looking at the low and high levels.

d. The Scenario. The battles were simulated in the current time frame. Five Blue tanks (M60A1) were defending against 25 Red tanks (T62). No other weapons were played in the simulation.

e. EEA/MOE.

(1) Essential elements of analysis: What are the relative outcomes of simulated tank battles in which Blue tanks are and are not camouflaged?

(2) Measures of effectiveness.

(a) Plotted percentages remaining of Red and Blue forces.

(b) Plotted surviving force ratio differential calculated as follows:

$$\frac{\text{Blue percent remaining} - \text{Red percent remaining}}{100}$$

(c) Plotted Red and Blue losses versus range.

f. Assumptions.

(1) The presumed relationships between individual cumulative times and calculated average times spent in previous range bands are valid (appendixes A, B, C, and D).

(2) BLDM portrays the data realistically within the bounds of a yes/no answer.

g. Limitations. Simulation results within 2,000 meters are not based on firm empirical data.

10

3. COMPARISONS AND CONCLUSIONS.

   a. Comparisons. The following results were found by comparing the appropriate runs from table 3 using the plotted MOE of appendix F.

      (1) The expansion process was favorable to the Red force but in no case was a trend reversed; therefore, the expansion process is not relevant to any conclusions to be drawn.

      (2) Camouflage makes a contribution to the effectiveness of the Blue force. However, of almost equal importance is the firing acquisition emphasis. If firing acquisition is emphasized, camouflage is of very slight importance. But if firing acquisition is not emphasized, camouflage is extremely important.

      (3) Non-emphasis of firing acquisition favors the effectiveness of the Blue force. No distinction can be made as to whether non-emphasis is a smaller, equal, or greater contributor to Blue survival than camouflage.

   b. Conclusions.

      (1) Camouflage contributes to the military worth of tanks by decreasing nonfiring acquisition rates.

      (2) The size of contribution of camouflage to military worth is dependent on both firing and nonfiring acquisition rates.

      (3) This military worth consists of both more Red losses and fewer Blue losses.

      (4) The military worth of camouflage cannot be conclusively established because of the undefined relationship between firing and non-firing acquisition rates and lack of critical data on acquisition at close ranges.

      (5) There is a need for field data that address firing acquisition rates, preferably collected in conjunction with data addressing nonfiring acquisition rates.

APPENDIX A

TEST DATA - STATIC PATTERN-PAINTED TANK

APPENDIX A

TEST DATA - STATIC PATTERN-PAINTED TANK

A-1. The table below represents range and cumulative time for individual acquisitions of the static pattern-painted tank. The range is the distance between observer and acquired pattern-painted tank. Each range and cumulative time pair is independent of all other acquisition pairs. (For a description of the data source, see CACDA/COA Technical Report of November 1976 titled Statistical Analysis Report of the M60A1 Camouflage Test and US Army Aberdeen Proving Ground Test Plan, January 1976, titled Camouflage Applications on M60A1 Tanks by Nancy S. Hill.)

Table A-1. Test data (continued next page)

Range	Cumulative Time
2631	502
1731	731
3031	154
3131	160
2931	272
1795	963
1631	997
2331	568
2631	387
1631	1062
1531	1073
1795	870
1495	895
1795	895
2031	819
2331	525
2331	673
3131	185

Table A-1. Test data (concluded)

Range	Cumulative Time
2331	592
1595	1007
2794	270
1676	772
2275	389
2375	275
2075	587
3275	263
1810	622
1909	522
1909	506
1810	620

A-2. The table below shows the range and cumulative time pairs listed by descending range and grouped in bands of approximately 500 meters. "Approximate" 500 meter bands are necessary to correspond with slight inconsistencies in the test data. The mean cumulative time for each group is calculated.

Table A-2. Test data grouped (continued next page)

Range (3000-2500m)	Cumulative Time
3275	263
3131	185
3131	160
3031	154
2931	272
2794	270
2631	387
2631	502
	2193

$$\overline{T}_{cum} = \frac{2193}{8} = 274 \text{ seconds}$$

Table A-2. Test data grouped (concluded)

Range (2500-2000m)	Cumulative Time
2735	275
2331	525
2331	673
2331	592
2331	568
2275	389
2075	587
2031	819
	4428

$$\overline{T}_{cum} = \frac{4428}{8} = 554 \text{ seconds}$$

Range (2000-1500m)	Cumulative Time
1909	522
1909	506
1810	620
1810	622
1795	963
1795	870
1795	895
1731	731
1676	772
1631	997
1631	1062
1595	1007
1531	1073
1495	895
	11535

$$\overline{T}_{cum} = \frac{11535}{14} = 823 \text{ seconds}$$

A-3. The calculations of acquisition rates for the respective range bands are presented below.

    a. <u>Range (3000m-2500m)</u>.

n_i = number of acquisitions within this range band = 8

n_p = number of possible acquisitions = 38

$\overline{T}_{cum(i)}$ = mean cumulative time for an acquisition within this range = 274 seconds

$\overline{T}_{cum(i-1)}$ = average cumulative time for an acquisition within the next greater range band = 0

λ = acquisition rate (seconds)

$$\lambda = \frac{\dfrac{n_i}{n_p}}{\left| (\overline{T}_{cum(i-1)} - \overline{T}_{cum(i)}) \right|} \qquad\qquad = \frac{\dfrac{8}{38}}{274}$$

$$= .000768$$

    b. <u>Range (2500m-2000m)</u>.

n_i = number of acquisitions within this range band = 8

n_p = number of possible acquisitions = 30

$\overline{T}_{cum(i)}$ = mean cumulative time for an acquisition within this band = 554 seconds

$\overline{T}_{cum(i-1)}$ = average cumulative time for an acquisition within the next greater range band = 274 seconds

λ = acquisition rate (seconds)

$$\lambda = \frac{\dfrac{n_i}{n_p}}{\left| (\overline{T}_{cum(i-1)} - \overline{T}_{cum(i)}) \right|} \qquad\qquad = \frac{\dfrac{8}{30}}{274-554}$$

$$= .000952$$

c. <u>Range (2000m-1500m)</u>.

n_i = number of acquisitions within this range band = 14

n_p = number of possible acquisitions = 22

$\overline{T}_{cum_{(i)}}$ = mean cumulative time for an acquisition within this band = 823

$\overline{T}_{cum_{(i-1)}}$ = average cumulative time for an acquisition within the next greater range band = 554

λ = acquisition rate (per second)

$$\lambda = \frac{\dfrac{n_i}{n_p}}{\left| \left(\overline{T}_{cum_{(i-1)}} - \overline{T}_{cum_{(i)}} \right) \right|} = \frac{\dfrac{14}{22}}{554-823}$$

$$= .002366$$

A-5

APPENDIX B

TEST DATA - STATIC CAMOUFLAGED (TEST) TANK

APPENDIX B

TEST DATA - STATIC CAMOUFLAGED (TEST) TANK

B-1. The table below represents range and cumulative time for individual acquisitions of the static camouflaged (test) tank. The range is the distance between observer and acquired camouflaged tank. Each range and cumulative time pair is independent of all other acquisition pairs. (For a description of the data source, see CACDA/ COA Technical Report of November 1976 titled Statistical Analysis Report of the M60A1 Camouflage Test and US Army Aberdeen Proving Ground Test Plan, January 1976, titled Camouflage Applications on M60A1 Tanks by Nancy S. Hill.)

Table B-1. Test data

Range	Cumulative Time
1908	506
2593	260
3093	25
2993	164
2693	436
2893	400
2293	670
2293	652

B-2. The table below shows the range and cumulative time pairs listed by descending range and grouped in bands of approximately 500 meters. "Approximate" 500 meter bands are necessary to correspond with slight inconsistencies in the test data. The mean cumulative time for each group is calculated.

Table B-2. Test data grouped

Range (3000-2500m)	Cumulative Time
3093	25
2993	164
2893	400
2693	436
	1025

$$\overline{T}_{cum} = \frac{1025}{4} = 256 \text{ seconds}$$

Range (2500-2000m)	Cumulative Time
2593	260
2293	670
2293	652
1908	506
	2088

$$\overline{T}_{cum} = \frac{2088}{4} = 522 \text{ seconds}$$

B-3. The calculations of acquisition rates for the respective range bands are presented below.

a. Range (3000m-2500m).

n_i = number of acquisitions within this range band = 4

n_p = number of possible acquisitions = 38

$\overline{T}_{cum(i)}$ = mean cumulative time for an acquisition within this band = 256 seconds

$\overline{T}_{cum(i-1)}$ = average cumulative time for an acquisition within the next greater range band = 0

λ = acquisition rate (seconds)

B-2

$$\lambda = \frac{\dfrac{n_i}{n_p}}{\left| (\overline{T}_{cum_{(i-1)}} - \overline{T}_{cum_{(i)}}) \right|} \qquad\qquad = \frac{\dfrac{4}{38}}{256}$$

$$= .000411$$

b. Range (2500m-2000m).

n_i = number of acquisitions within this range band = 4

n_p = number of possible acquisitions ≈ 34

$\overline{T}_{cum_{(i)}}$ = mean cumulative time for an acquisition within this band = 522 seconds

$\overline{T}_{cum_{(i-1)}}$ = average cumulative time for an acquisition within the next greater range band = 256 seconds

λ = acquisition rate (per second)

$$\lambda = \frac{\dfrac{n_i}{n_p}}{\left| (\overline{T}_{cum_{(i-1)}} - \overline{T}_{cum_{(i)}}) \right|} \qquad\qquad = \frac{\dfrac{4}{34}}{256-522}$$

$$= .000442$$

APPENDIX C

TEST DATA - DYNAMIC PATTERN-PAINTED TANK

APPENDIX C

TEST DATA - DYNAMIC PATTERN-PAINTED TANK

C-1. The table below represents range and cumulative time for individual acquisitions of the dynamic pattern-painted tank. The range is the distance between observer and acquired pattern-painted tank. Each range and cumulative time pair is independent of all other acquisition pairs. All ranges for this group fall between 2000 and 1500m range. (For a description of the data source, see CACDA/COA Technical Report of November 1976 titled <u>Statistical Analysis Report of the M60A1 Camouflage Test</u> and US Army Aberdeen Proving Ground Test Plan, January 1976, titled <u>Camouflage Applications on M60A1 Tanks</u> by Nancy S. Hill.)

Table C-2. Test data (continued next page)

Range	Cumulative Time
1967	10
1878	37
1984	5
1937	19
1998	31
1835	50
1828	37
1844	32
1808	43
1782	57
1726	68
1802	45
1987	4
1927	22
1911	27
1974	8
1950	15
1901	25
1911	27

Table C-1. Test data (concluded)

Range	Cumulative Time
1950	19
1943	2
1868	25
1733	80
1947	16
1887	34
1957	13
1933	20
1953	14
1883	35
1924	23
1924	23
1873	38
1933	20
1890	33
1903	29
	980

$$\overline{T}_{cum} = \frac{980}{35} = 28 \text{ seconds}$$

C-2. The calculation of the acquisition rate for the range band is presented below:

n_i = number of acquisitions within this range band = 35

n_p = number of possible acquisitions = 59

$\overline{T}_{cum(i)}$ = mean cumulative time for an acquisition within this band = 28 seconds

$\overline{T}_{cum(i-1)}$ = average cumulative time for an acquisition within the next greater range band = 0

C-2

λ = acquisition rate (per second)

$$\lambda = \dfrac{\dfrac{n_i}{n_p}}{\left| (\overline{T}_{cum_{(i-1)}} - \overline{T}_{cum_{(i)}}) \right|} \qquad = \dfrac{\dfrac{35}{59}}{(28)} = .0212$$

APPENDIX D

TEST DATA - DYNAMIC CAMOUFLAGED (TEST)TANK

APPENDIX D

TEST DATA - DYNAMIC CAMOUFLAGED (TEST) TANK

D-1. The table below represents range and cumulative time for individual acquisitions of the dynamic camouflaged (test) tank. The range is the distance between observer and acquired camouflaged tank. Each range and cumulative time pair is independent of all other acquisition pairs. All ranges for this group fall between 2000 and 1500m range. (For a description of the data source, see CACDA/COA Technical Report of November 1976 titled Statistical Analysis Report of the M60A1 Camouflage Test and US Army Aberdeen Proving Ground Test Plan, January 1976, titled Camouflage Applications on M60A1 Tanks by Nancy S. Hill.)

Table D-1. Test data (continued next page)

Range	Cumulative Time
1918	25
1931	21
1984	5
1821	39
1815	41
1861	42
1852	45
1934	20
1950	15
1861	27
1891	18
1911	27
1871	24
1851	30
1861	27
1843	47
1937	19
1887	34

Table D-1. Test data (concluded)

Range	Cumulative Time
1933	20
1943	17
1974	8
1924	23
1934	20
1897	31
	625

$$\bar{T}_{cum} = \frac{625}{24} = 26 \text{ seconds}$$

D-2. The calculation of the acquisition rate for the range band is presented below:

n_i = number of acquisitions within this range band = 24

n_p = number of possible acquisitions = 59

$\bar{T}_{cum(i)}$ = mean cumulative time for an acquisition within this band = 26 seconds

$\bar{T}_{cum(i-1)}$ = average cumulative time for an acquisition within the next greater range band = 0

λ = acquisition rate (per second)

$$\lambda = \frac{\frac{n_i}{n_p}}{\left| (\bar{T}_{cum(i)} - \bar{T}_{cum(i-1)}) \right|} = \frac{\frac{24}{59}}{26}$$

$$= .0156$$

APPENDIX E

EXPANSION OF ACQUISITION RATES OVER REQUIRED RANGES

APPENDIX E

EXPANSION OF ACQUISITION RATES OVER REQUIRED RANGES

E-1. PATTERN-PAINTED - STATIC TEST DATA.

    a. By assuming λ fits a negative exponential equation for all range bands, a systematic method evolves for calculating λ for range bands 1, 2, and 3.

    b. The available data for this set of circumstances include:

Range Band (X)	Range Bounds	(Acquisition Rate)	$\ln(\lambda)$
6	2500-3000m	.000768	-7.171
5	2000-2500m	.000952	-6.956
4	1500-2000m	.002366	-6.047

    c. Based on the assumption of 1.a. above, a plot of $\ln(\lambda)$ versus their respective range bands will yield a straight line. The development of the equation of this straight line follows:

    Since a straight line is being fit to three data points, linear regression analysis is used:

The equation of the line is of the form

$$\ln(\lambda) = a + b \cdot X$$

with

$$b = \frac{n \sum X \cdot \ln(\lambda) - (\sum X)(\sum \ln(\lambda))}{n \sum X^2 - (\sum X)^2}$$

and

$$a = \overline{\ln(\lambda)} - b \, \overline{X}$$

The elements of the equations for "a" and "b" are calculated in the following table:

X	$\ln(\lambda)$	$X \cdot \ln(\lambda)$	X^2	$\ln(\lambda)^2$
4	-6.047	-24.188	16	36.57
5	-6.956	-34.78	25	48.39
6	-7.171	-43.026	36	51.42
Total 15	-20.174	-101.994	77	136.38

$n = 3$

$$\overline{X} = \frac{15}{3} = 5$$

$$\overline{\ln(\lambda)} = \frac{-20.174}{3} = -6.725$$

$$b = \frac{3(-101.994) - 15(-20.174)}{3(77) - (15)^2} = -.562$$

$$a = (-6.725) - (-.562)(5) = -3.91$$

The resulting equation is:

$$\ln(\lambda) = X(-.562) -3.91$$

d. Calculation of λ for range bands 1, 2, and 3 is detailed in the table below:

X	$X(-.562) -3.91 = \ln(\lambda)$	$e^{(X(-.562) -3.91)} = X$
1	-4.472	.01142
2	-5.034	.00651
3	-5.596	.00371

E-2. CAMOUFLAGED PATTERN-PAINTED - STATIC TEST DATA.

a. To reiterate, by assuming λ fits a negative exponential equation for all range bands, a systematic method evolves for calculating λ for bands 1, 2, 3, and 4.

b. The available data for this set of circumstances include:

Range Band (X)	Range Bounds	(Acquisition Rate)	$\ln(\lambda)$
6	2500-3000m	.000411	-7.796
5	2000-2500m	.000442	-7.724

c. Based on the assumption of 2.a. above, a plot of $\ln(\lambda)$ versus their respective range bands will yield a straight line. The development of the equation of this straight line follows:

Since a straight line is being fit to two data points, a rudimentary approach is used:

The equation of the line is of the form

$$\ln(\lambda) = a + b \cdot X$$

with

$$b = \frac{\ln(\lambda)}{X}$$

and

$$a = \overline{\ln(\lambda)} - b\overline{X}$$

The elements of the equations for "a" and "b" are calculated below:

$$\Delta \ln(\lambda) = (-7.796) - (-7.724) = -.072$$

and

$$X = 6-5 = 1$$

resulting in

$$b = \frac{-.072}{1} = -.072$$

$$\overline{X} = \frac{6 + 5}{2} = 5.5$$

$$\overline{\ln(\lambda)} = \frac{(-7.796) + (-7.724)}{2} = -7.76$$

$$a = (-7.76) - (-.072)(5.5) = -7.364$$

The resulting equation is

$$\ln(\lambda) = X(-.072) - 7.364$$

d. Calculation of λ for range bands 1, 2, 3, and 4 is detailed in the table below:

X	$X(-.072) - 7.364 = \ln(\lambda)$	$e^{\{X(-.072) - 7.364\}}$
1	-7.436	.000590
2	-7.508	.000549
3	-7.58	.000511
4	-7.652	.000475

E-3. DYNAMIC TEST DATA.

a. Since there is only one data point representing camouflaged dynamic and one data point representing pattern-painted dynamic, and since their values are relatively close, their average is taken as a single data point. In addition to the negative exponential assumptions of paragraphs 1.a. and 2.a., another assumption is necessary. This assumption is that the slope of the resulting equation of paragraph 1.d. is accurate for the dynamic acquisition rates.

b. The available data for this set of circumstances include:

Range Band (X)	Range Bounds	Circumstances	
4	1500-2000m	Pattern-Painted	.0212
4	1500-2000m	Camouflaged	.0156

c. Based on the assumptions of 3.a. above, a plot of ln λ versus their respective bands will yeild a straight line. The development of the equation of this straight line follows:

Since a straight line is being fit to one data point and a line's slope, the following approach is used.

The equation of the line is of the form

$$\ln(\lambda) = a + bX$$

with

$$b = (-.562)$$

$$\overline{\ln(\lambda)} = \frac{\ln(.0212) + \ln(.0156)}{2} = \frac{-3.854 - 4.16}{2} = -4.007$$

$$X = 4$$

$$a = -4.007 - (-.562)(4) = -1.759$$

The resulting equation is

$$\ln(\lambda) = (-.562)X - 1.759$$

d. A calculation of λ for range bands 1, 2, 3, 5, and 6 is detailed in the table below:

X	X(-.562) - 1.759 = ln(λ)	$e^{\{X(-.562) - 1.759\}}$
1	-2.321	.09818
2	-2.883	.05597

X	$X(-.562) - 1.759 = \ln(\lambda)$	$e^{\{X(-.562) - 1.759\}}$
3	-3.445	.03191
5	-4.569	.010368
6	-5.131	.00591

APPENDIX F

PLOTTED MOE

Table F-1. Contrasting factor - expansion of data

Runs Being Compared	Result of Expansion	Comparison
1 & 3	Slight decrease in Red losses (Red wins)	The expansion process was favorable to the Red force but in no case was a trend reversed. Therefore, the expansion process is not relevant to any conclusions to be drawn.
2 & 4	Slight decrease in Red losses (Red wins)	The expansion process was favorable to the Red force but in no case was a trend reversed. Therefore, the expansion process is not relevant to any conclusions to be drawn.
1P & 3P	Slight increase in Blue losses (Blue wins)	The expansion process was favorable to the Red force but in no case was a trend reversed. Therefore, the expansion process is not relevant to any conclusions to be drawn.
2P & 4P	Slight increase in Blue losses (Blue wins)	The expansion process was favorable to the Red force but in no case was a trend reversed. Therefore, the expansion process is not relevant to any conclusions to be drawn.

Table F-2. Contrasting factor - camouflage

Runs Being Compared	Result of Blue using Camouflage	Comparison
1 & 2	Exceedingly small change in results, to Blue's favor (Red wins)	Camouflage makes a contribution to the effectiveness of the Blue force. However, of almost equal importance is the firing acquisition emphasis. If firing acquisition is emphasized, camouflage is of very slight importance. But if firing acquisition is not emphasized, camouflage is extremely important.
3 & 4	Exceedingly small change in results, to Blue's favor (Red wins)	Camouflage makes a contribution to the effectiveness of the Blue force. However, of almost equal importance is the firing acquisition emphasis. If firing acquisition is emphasized, camouflage is of very slight importance. But if firing acquisition is not emphasized, camouflage is extremely important.
1P & 2P	A trend reversal occurs if Blue uses camouflage (Blue wins instead of Red)	Camouflage makes a contribution to the effectiveness of the Blue force. However, of almost equal importance is the firing acquisition emphasis. If firing acquisition is emphasized, camouflage is of very slight importance. But if firing acquisition is not emphasized, camouflage is extremely important.
3P & 4P	A trend reversal occurs if Blue uses camouflage (Blue wins instead of Red)	Camouflage makes a contribution to the effectiveness of the Blue force. However, of almost equal importance is the firing acquisition emphasis. If firing acquisition is emphasized, camouflage is of very slight importance. But if firing acquisition is not emphasized, camouflage is extremely important.

Table F-3. Contrasting factor - emphasis of firing acquisition

| Runs Being Compared	Result of Emphasizing Firing Acquisition	Comparison
1 & 1P	If firing acquisition is emphasized, Red wins heavily. This is reversed if firing acquisition is not emphasized.	Non-emphasis of firing acquisition favors the effectiveness of the Blue force. No distinction can be made as to whether non-emphasis is a smaller, equal, or greater contributor to Blue survival than camouflage.
3 & 3P	If firing acquisition is emphasized, Red wins heavily. This is reversed if firing acquisition is not emphasized.	Non-emphasis of firing acquisition favors the effectiveness of the Blue force. No distinction can be made as to whether non-emphasis is a smaller, equal, or greater contributor to Blue survival than camouflage.
2 & 2P	If firing acquisition is emphasized, Red wins heavily. Red wins, but not so decisively if firing acquisition is not emphasized.	Non-emphasis of firing acquisition favors the effectiveness of the Blue force. No distinction can be made as to whether non-emphasis is a smaller, equal, or greater contributor to Blue survival than camouflage.
4 & 4P	If firing acquisition is emphasized, Red wins heavily. Red wins, but not so decisively if firing acquisition is not emphasized.	Non-emphasis of firing acquisition favors the effectiveness of the Blue force. No distinction can be made as to whether non-emphasis is a smaller, equal, or greater contributor to Blue survival than camouflage.

F-3
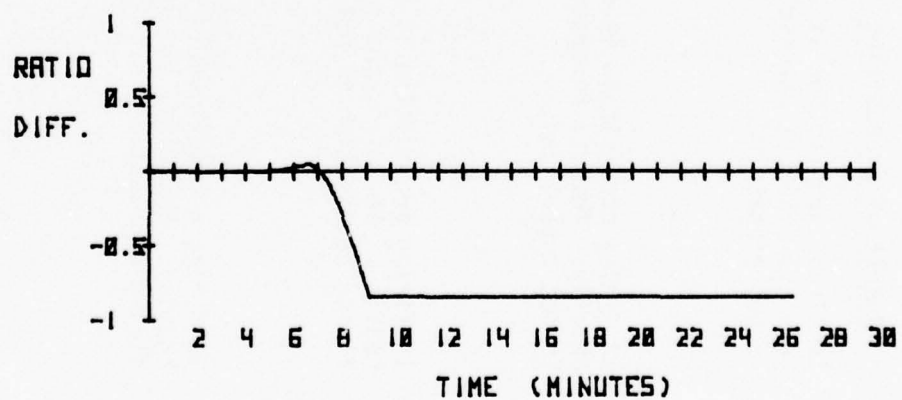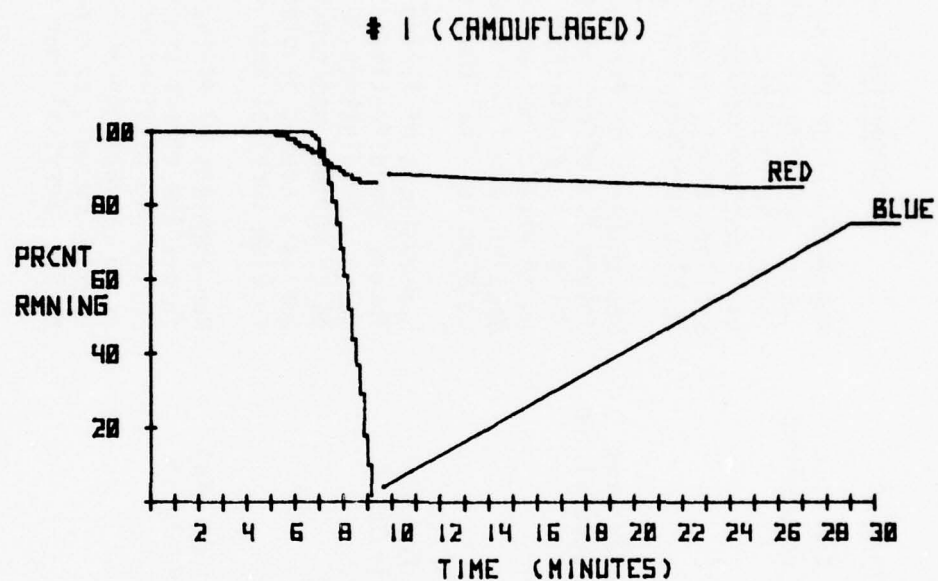
‡ I (CAMOUFLAGED)

Figure F-1.   Run #1.   Percent remaining and surviving force ratio differential
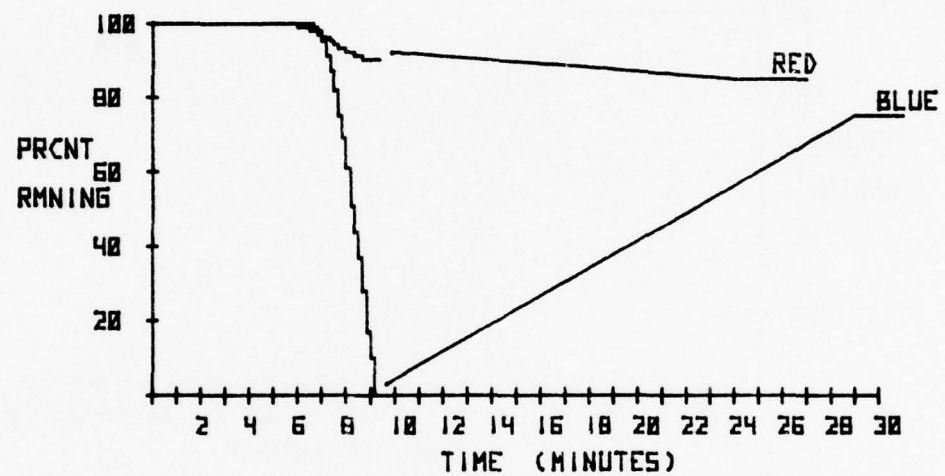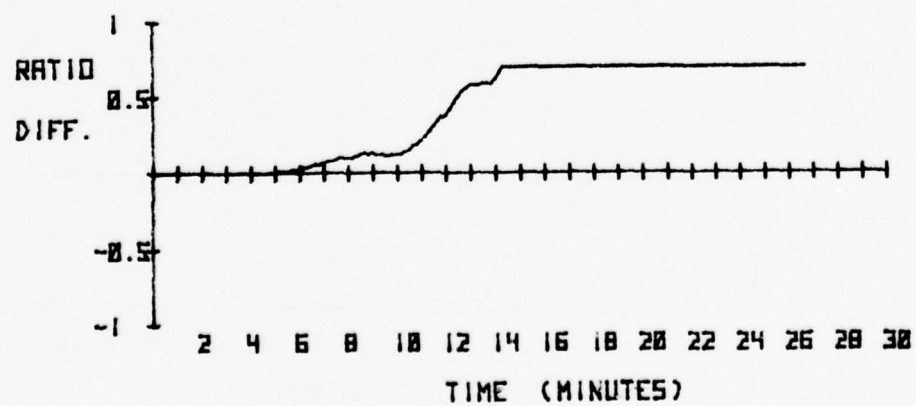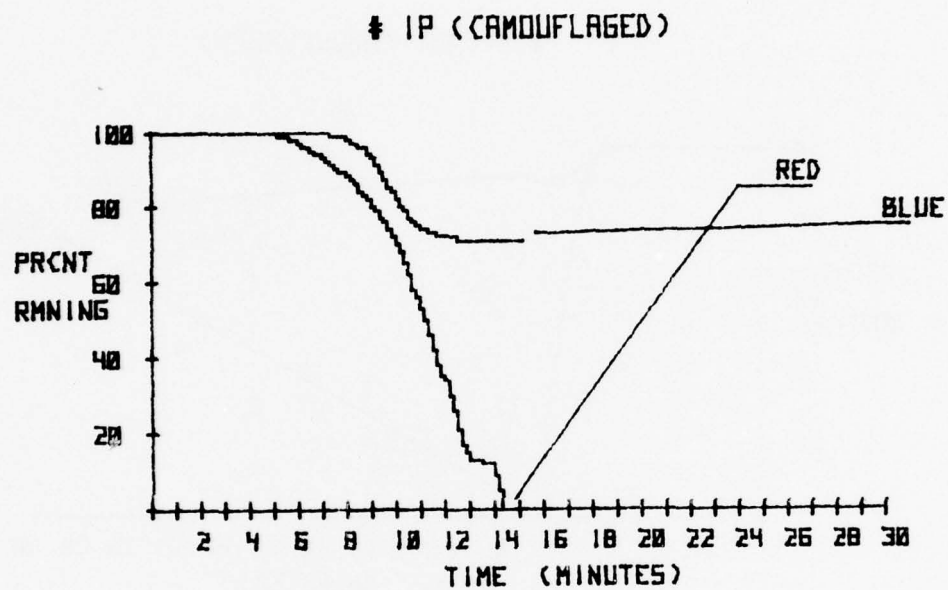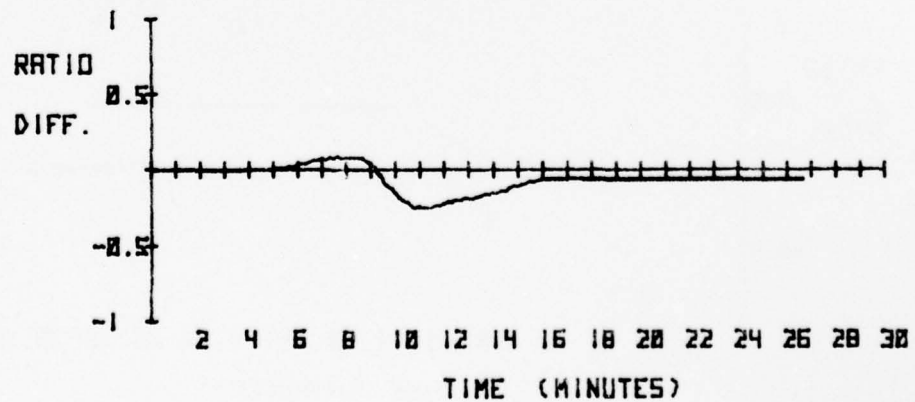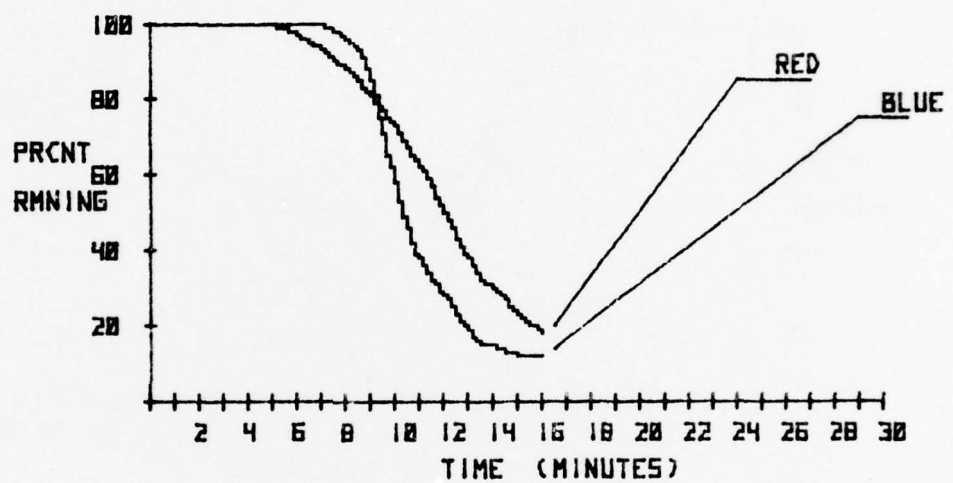
2 (NOT CAMOUFLAGED)
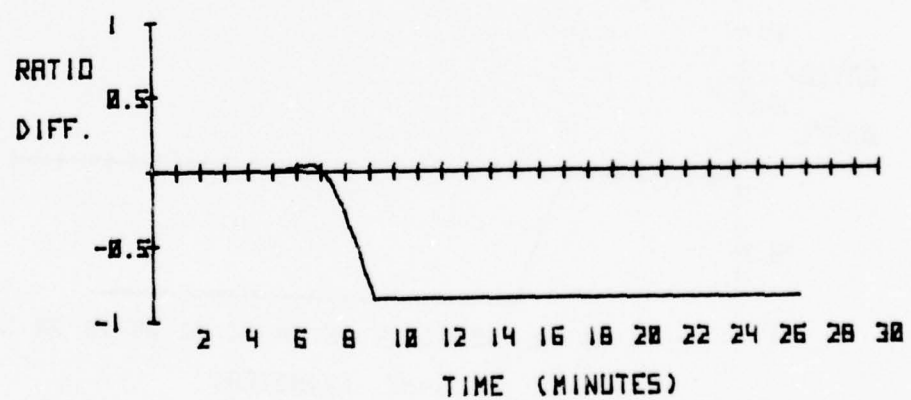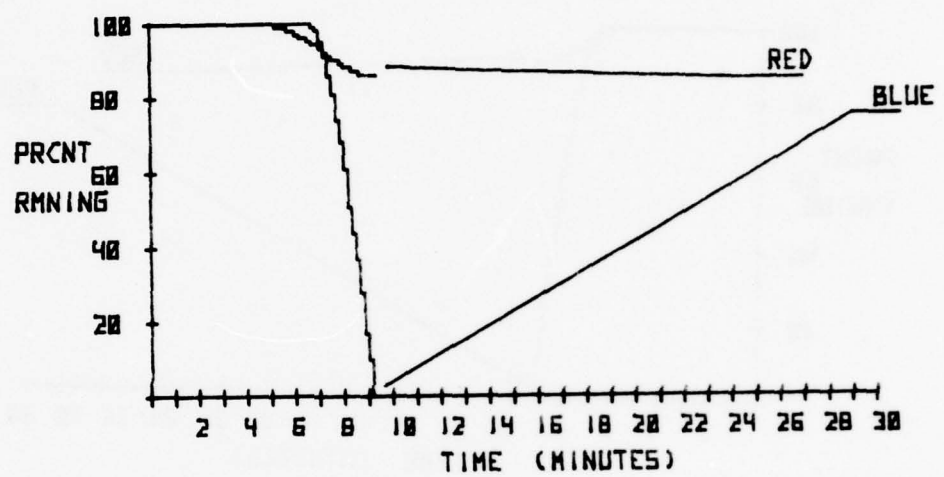
Figure F-2. Run #2. Percent remaining and surviving force ratio differential
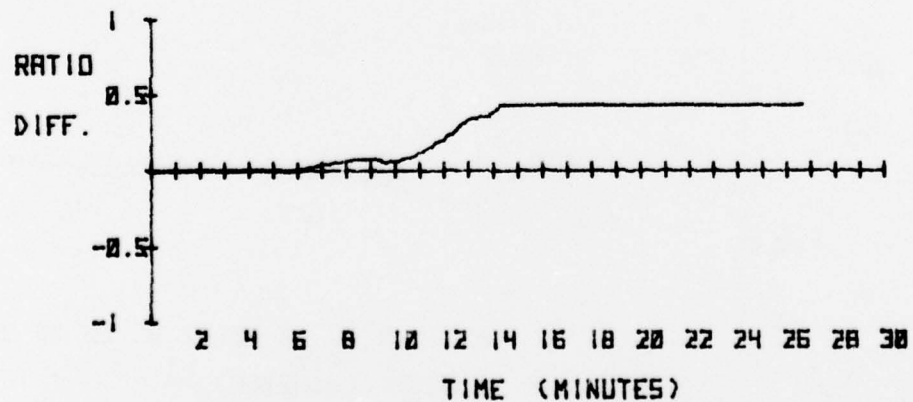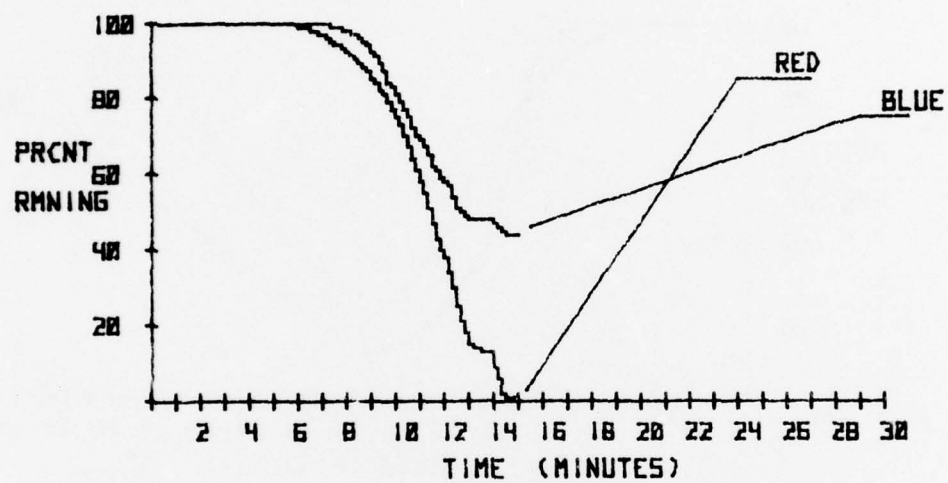
3 (CAMOUFLAGED)
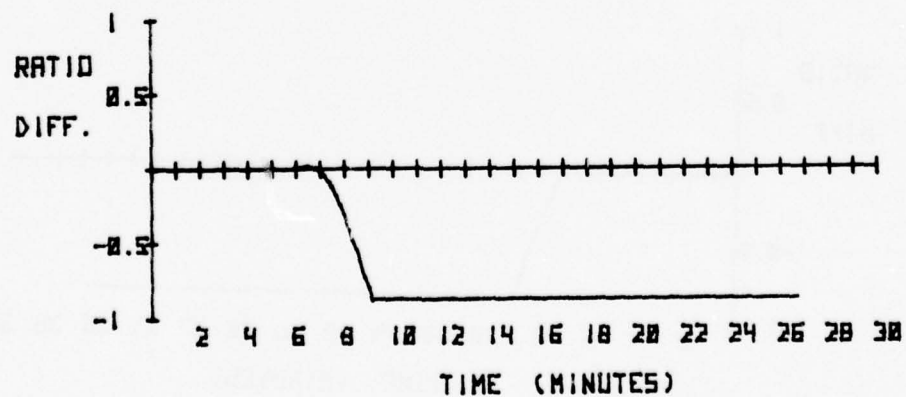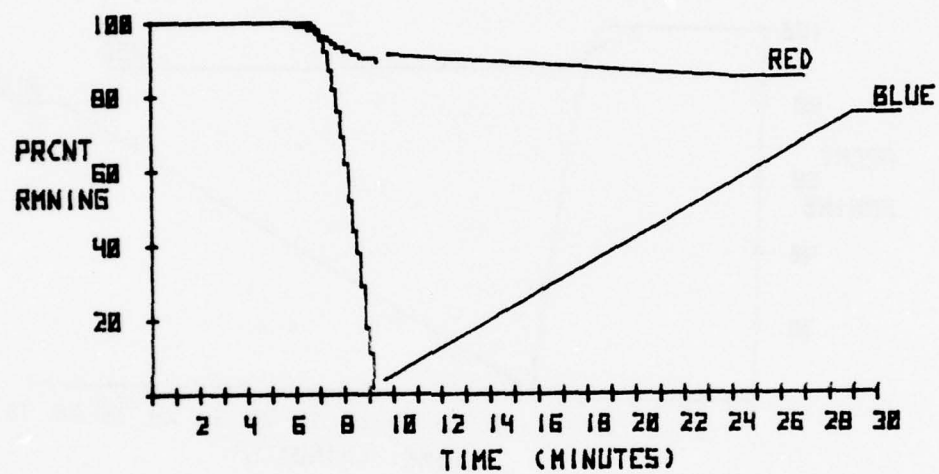
Figure F-3. Run #3. Percent remaining and surviving force ratio differential
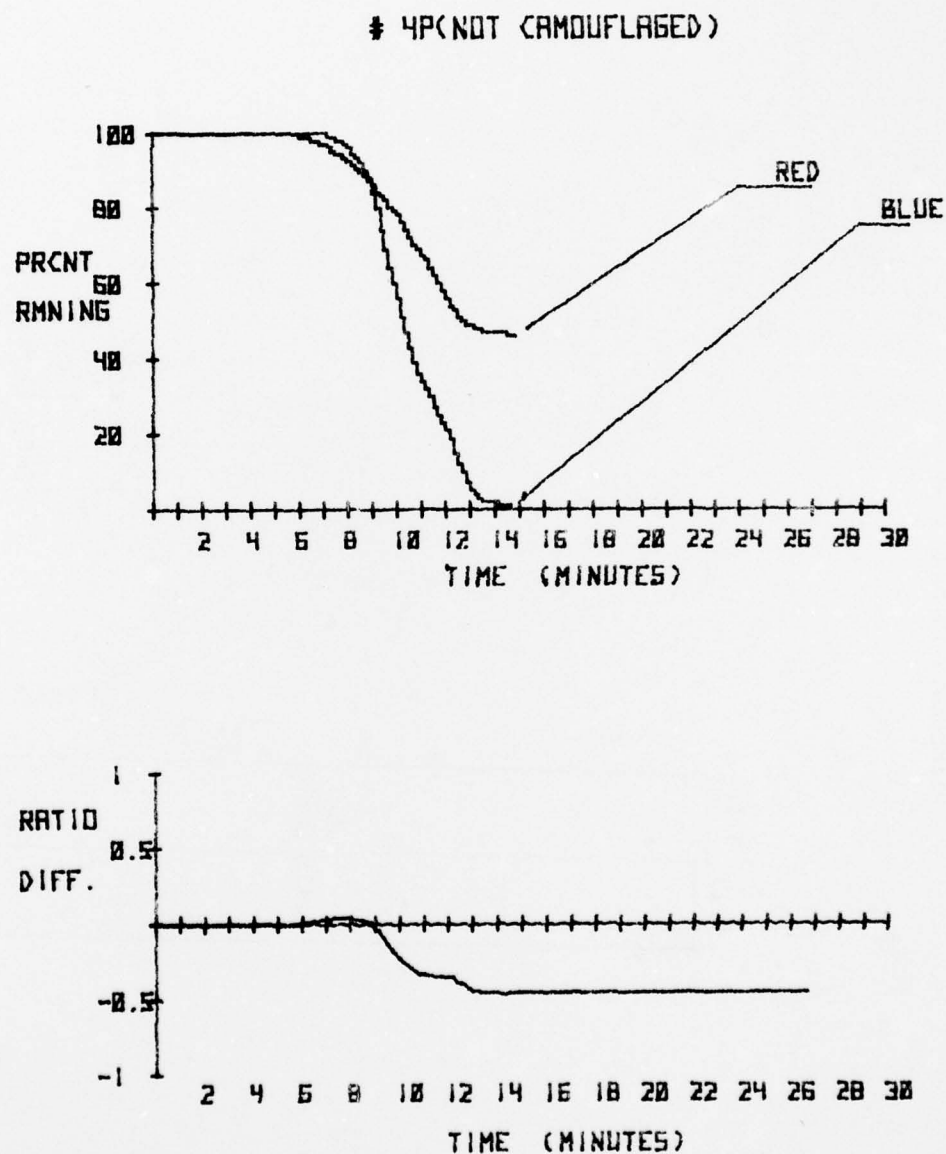
4 (NOT CAMOUFLAGED)
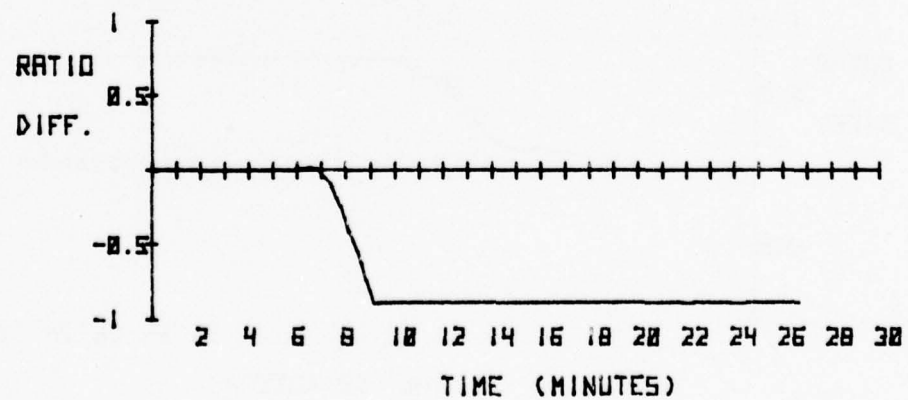
Figure F-4. Run #4. Percent remaining and surviving force ratio differential

IP (CAMOUFLAGED)

Figure F-5. Run #1P. Percent remaining and surviving force ratio differential

2P (NOT CAMOUFLAGED)

Figure F-6. Run #2P. Percent remaining and surviving force ratio differential

3P (CAMOUFLAGED)

Figure F-7. Run #3P. Percent remaining and surviving force ratio differential

4P(NOT (CAMOUFLAGED))

Figure F-8. Run #4P. Percent remaining and surviving force ratio differential

Runs 1 (camouflaged) and 2 (not camouflaged)

DIFFERENCE IN BLUE LOSSES
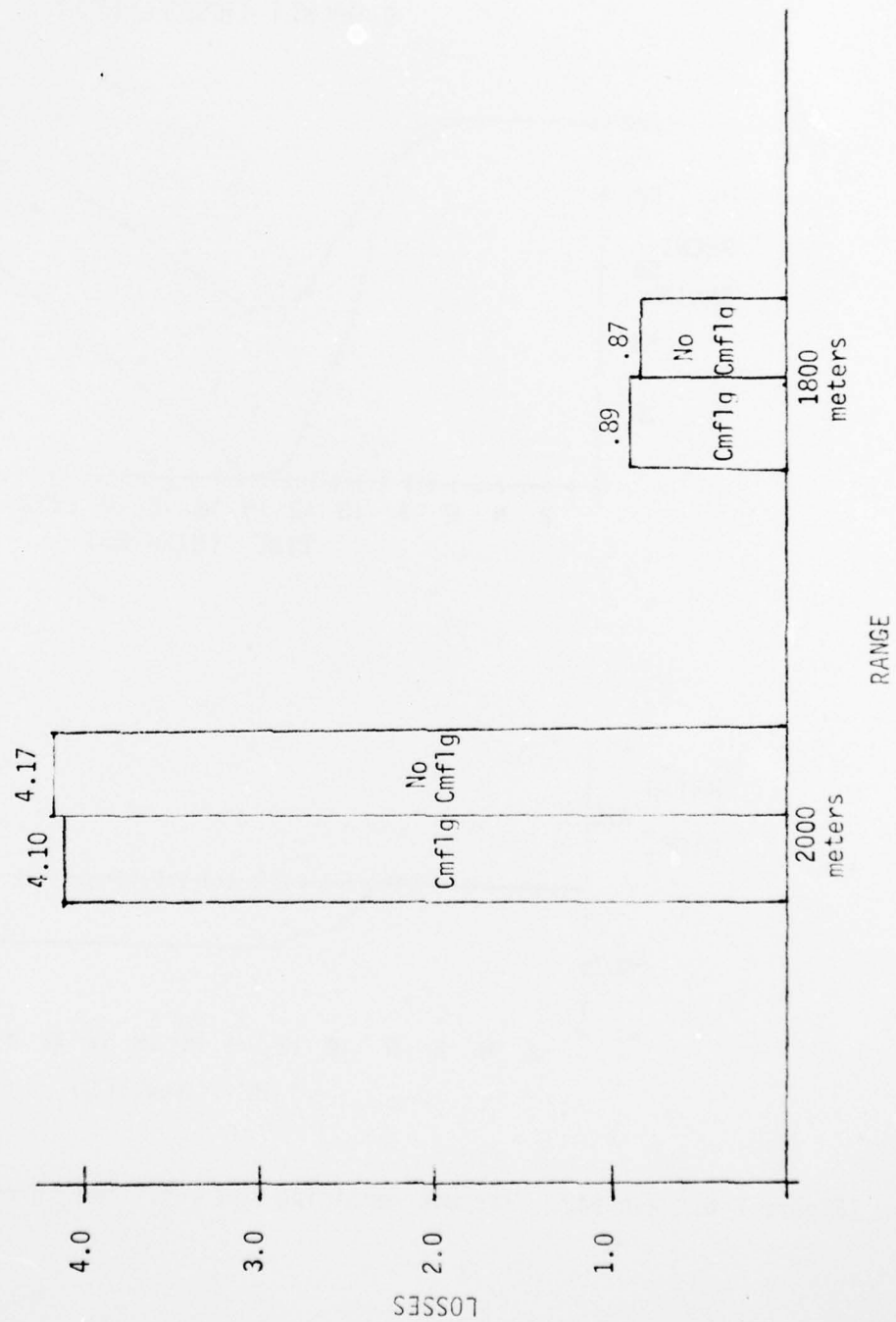
Figure F-9. Runs #1 & 2. Incremental losses versus range
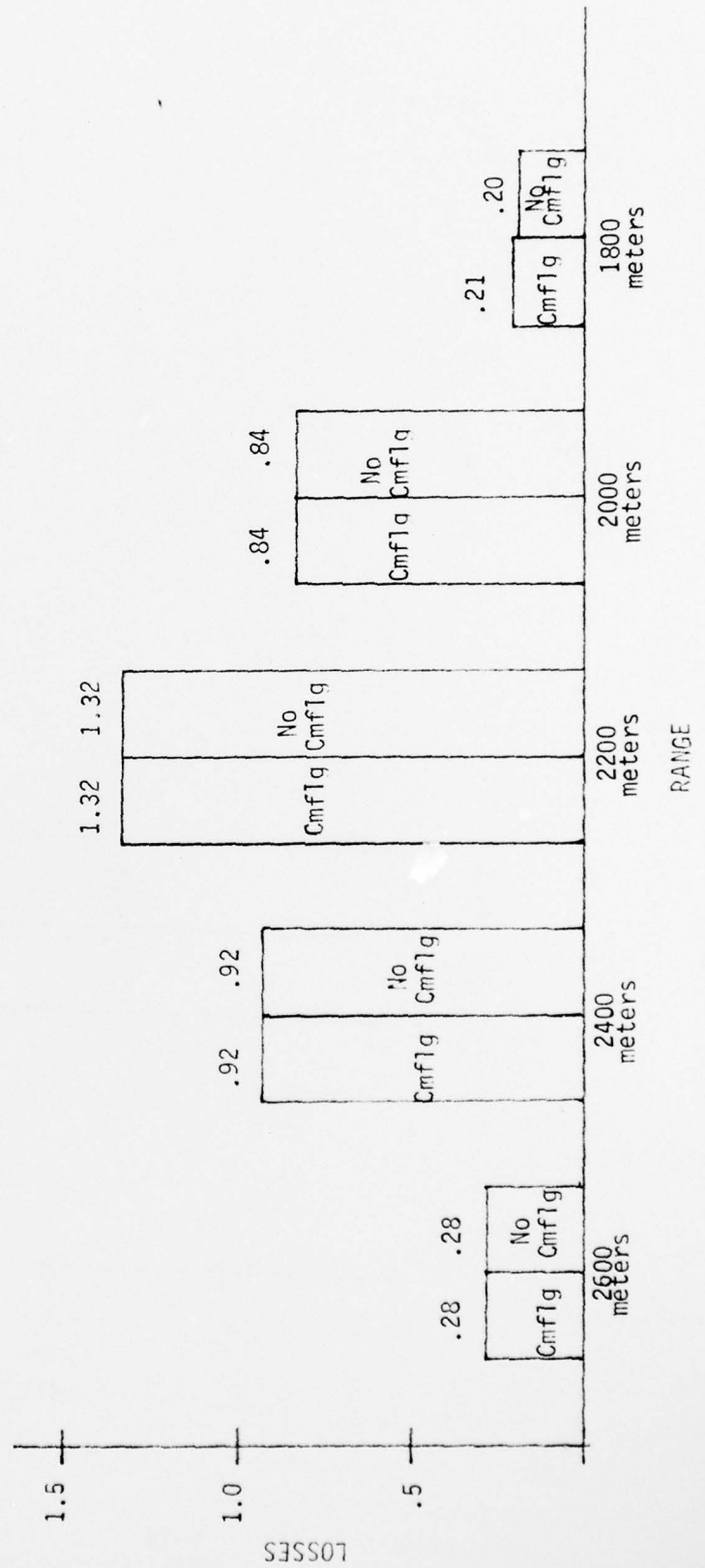
Runs 1 (camouflaged) and 2 (not camouflaged)

DIFFERENCE IN RED LOSSES

Figure F-10. Runs #1 & 2. Incremental losses versus range

Runs 3 (camouflaged) and 4 (not camouflaged)
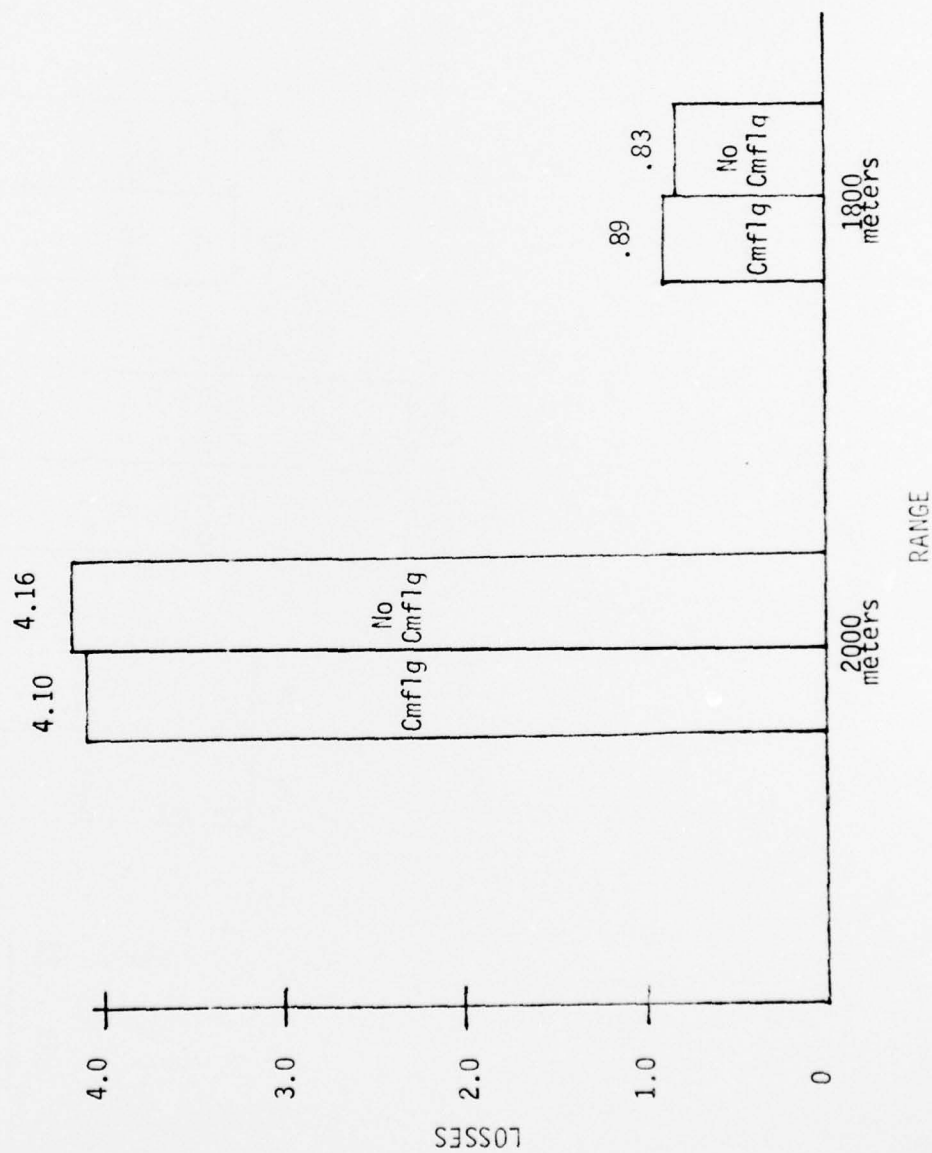
DIFFERENCE IN BLUE LOSSES

Figure F-11. Runs #3 & 4. Incremental losses versus range

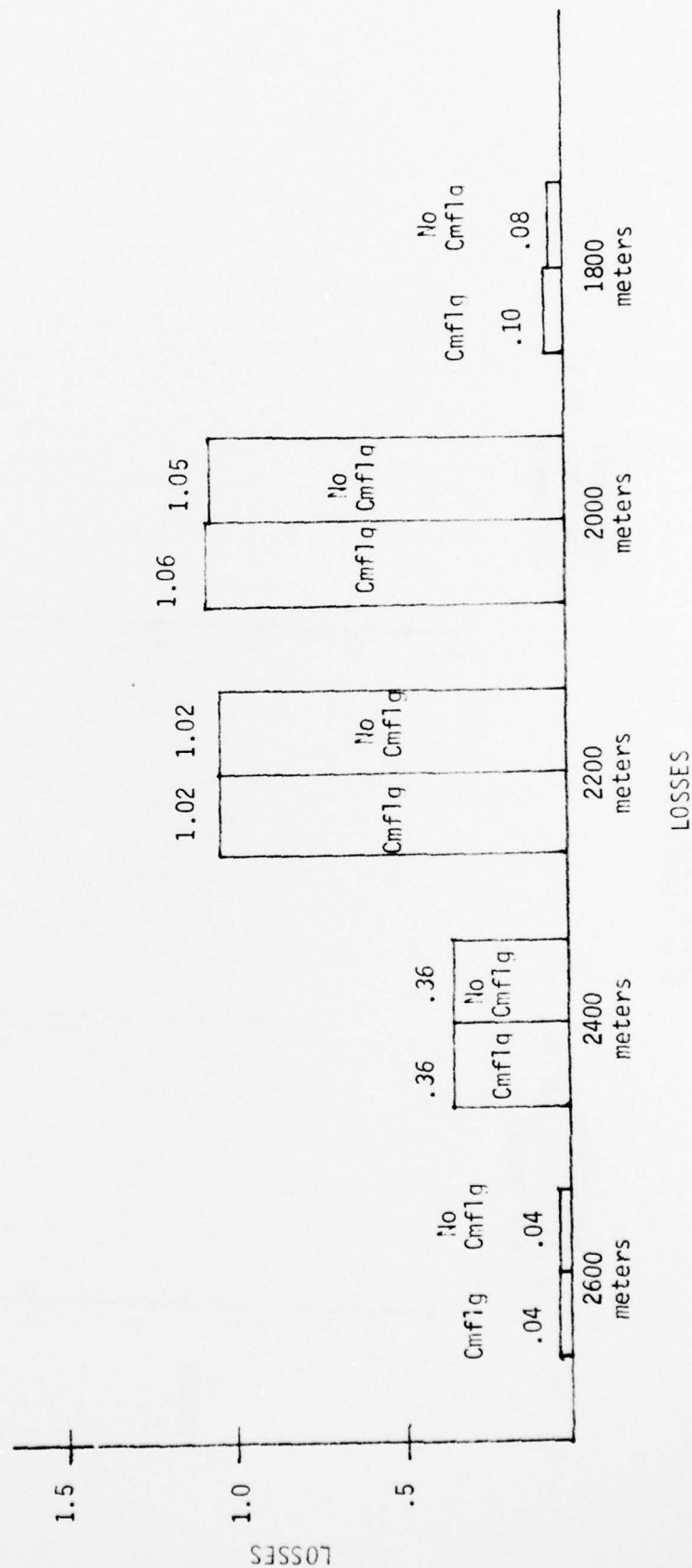Runs 3 (camouflaged) and 4 (not camouflaged)
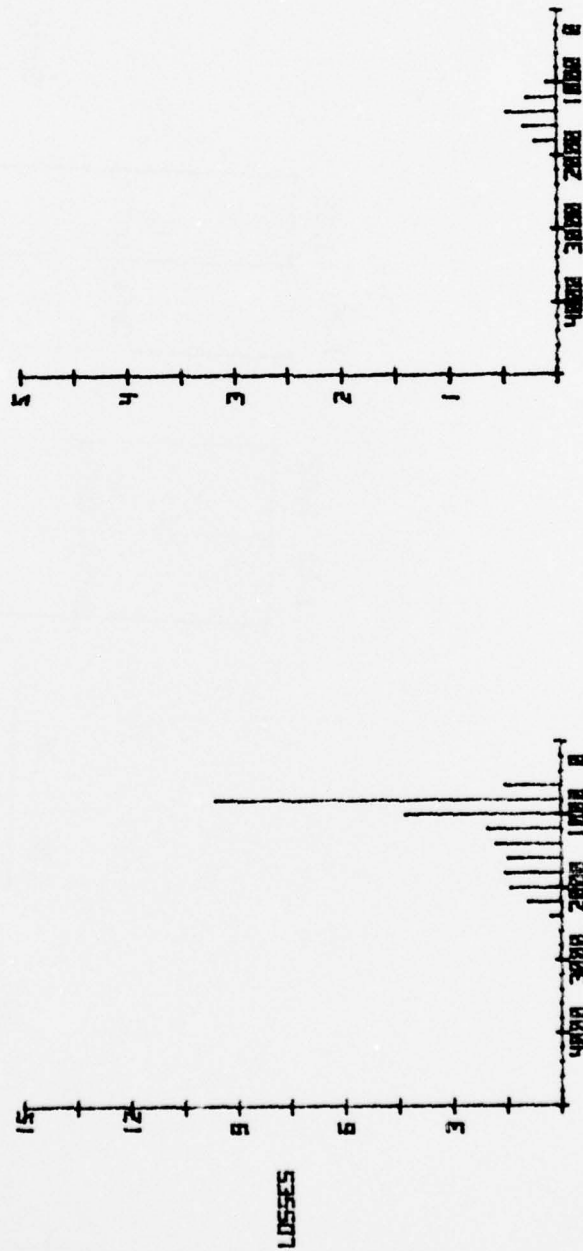
DIFFERENCE IN RED LOSSES

Figure F-12. Runs #3 & 4. Incremental losses versus range

LOSSES (INCREMENTAL VS.RNG.)
#1P (CAMOUFLAGED)

RED TANK(5)
KILLING 1.34 OF 5
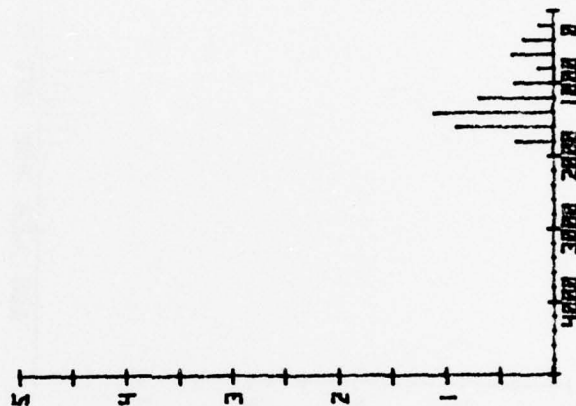BLUE TANK(5)

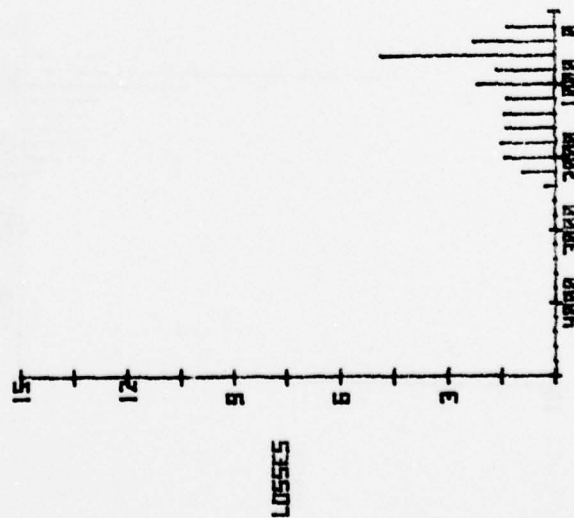BLUE TANK(5)
KILLING 24.95 OF 25
RED TANK(5)

RANGE (METERS)

LOSSES

Figure F-13. Run #1P. Incremental losses versus range
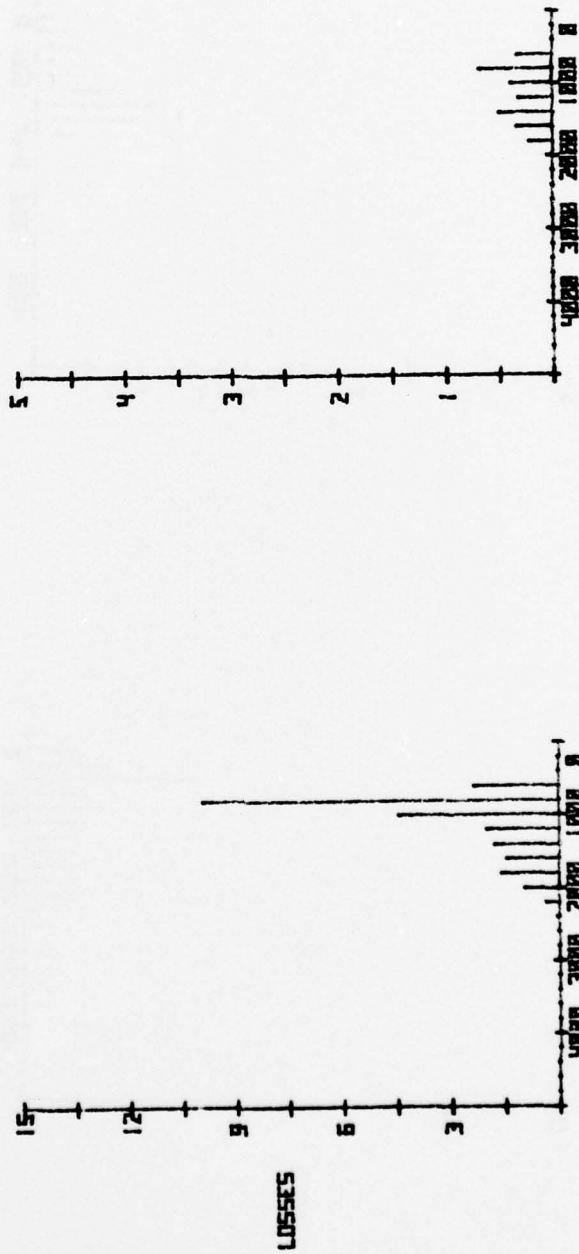
Figure F-14. Run #2P. Incremental losses versus range

LOSSES (INCREMENTAL VS.RNS.)
#3P (CAMOUFLAGED)

BLUE TANK(S)
KILLING 24.97   OF 25
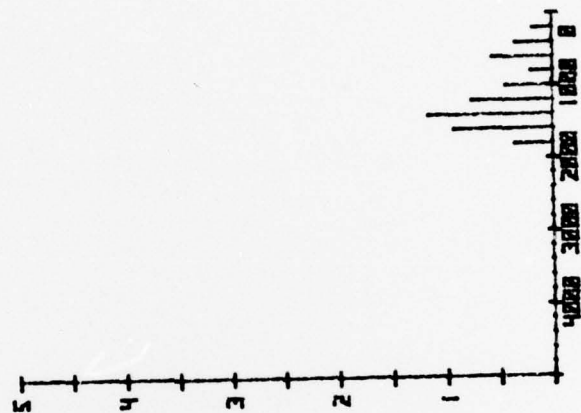RED TANK(S)

RED TANK(S)
KILLING 2.71   OF 5
BLUE TANK(S)

RANGE (METERS)
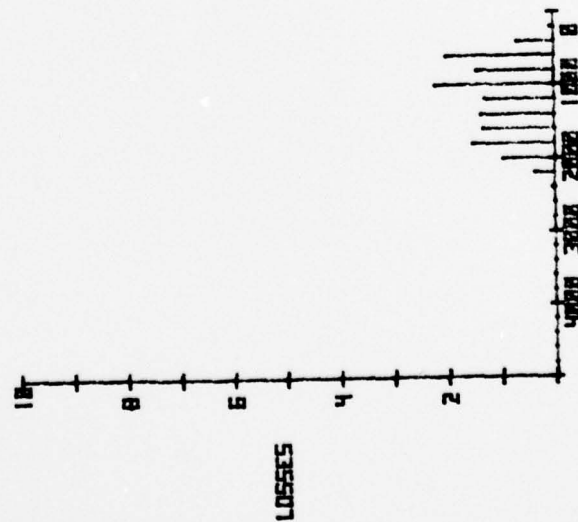
LOSSES

Figure F-15.   Run #3P.   Incremental losses versus range

Figure F-16. Run #4P. Incremental losses versus range

APPENDIX G

DISTRIBUTION LIST

Organization	No. of Copies

Commander 1
US Army Operational Test and Evaluation Agency
ATTN: DACS-TEM-F
Fort Belvoir, Virginia 22060

Commander 1
USATRADOC
ATTN: ATCD-AO
Fort Monroe, Virginia 23651

Commander 1
USATRADOC
ATTN: ATCD-DA
Fort Monroe, Virginia 23651

Commander 1
US Army Materiel Development and Readiness Command
ATTN: DRCDE-DC
Washington, D.C. 20315

Commander 1
USAARMS
ATTN: ATZK-CD-MS
Fort Knox, Kentucky 40121

Commander 1
US Army Concepts Analysis Agency
8120 Woodmont Avenue
ATTN: MOCA-SA
Bethesda, Maryland 20014

Commander 1
US Army Air Defense School
ATTN: ATSA-CD-ML
Fort Bliss, Texas 79906

Commander 1
US Army Aviation Center
ATTN: ATZQ-D-CC
Fort Rucker, Alabama 36360

DISTRIBUTION LIST (continued)

Organization	No. of Copies
Department of the Army Harry Diamond Laboratories ATTN: AMX-DO-DBA 2800 Powder Mill Road Adelphia, Maryland 20783	1
Commander US Army Ordnance Center and School ATTN: ATSL-CD-MS Aberdeen Proving Ground, Maryland 21005	1
Commander US Army Field Artillery School ATTN: ATSF-CD-MT Fort Sill, Oklahoma 73403	1
Project Manager AAH, USAAVSCOM ATTN: AMCPM-AAH-TM-W St. Louis, Missouri 63166	1
Defense Documentation Center Cameron Station Alexandria, Virigina 22314	2
Commander US Army Combat Developments Experimentation Command ATTN: Office of the Scientific Advisor	1

DCS, Experimentation
          C Experimentation Division
          Project Team I
	1
	1
	1

DCS, Program and Project Analysis	1
DCS, Instrumentation Fort Ord, California 93941	1
Commander US Army Tank Automative Systems Development Center ATTN: DRDTA-RHP Warren, Michigan 48090	1

Organization	No. of Copies
Commander US Army Infantry Center ATTN: ATZB-CD-CS Fort Benning, Georgia 31905	1
Commander USAECOM ATTN: DRSEL-WL-V Fort Monmouth, New Jersey 07703	1
Commander US Army Test and Evaluation Command ATTN: STEAP-MT-U Aberdeen Proving Ground, Maryland 21005	1
Commander Frankford Arsenal ATTN: SARFA-FCW-D Philadelphia, Pennsylavania 19137	1
Director USATRASANA ATTN: ATAA-TGA White Sands Missile Range, New Mexico 88002	1
Commander US Army Armament Command ATTN: AMSAR-RDG Rock Island, Illinois 61201	1
Commander US Army TRADOC Combined Arms Test Activity ATTN: ATCAT-CSS-SE Fort Hood, Texas 76544	1
Commander USAMSAA ATTN: DRX-SY-S Aberdeen Proving Ground, Maryland 21005	1

DISTRIBUTION LIST (concluded)

	No. of Copies
Organization	
Commander US Army Missile Command ATTN: DRSMI-RK Redstone Arsenal, Alabama 35809	1
Commander US Army Engineer Center ATTN: ATSE-CD-MS Fort Belvoir, Virginia 22060	1
Commander USAMERADCOM ATTN: DRX-FB-R Fort Belvoir, Virignia 22060	1